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UNDERSTORY VEGETATION, ASPEN REGENERATION, AND
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THE EFFECT OF CONTROLLED BURNING ON UNDERSTORY VEGETATION,ASPEN REGENERATION, AND SOIL NITROGEN IN THE ASPEN-BUNCHGRASS TYPE

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Final report for Research Grant No. RM-80-111-GR (EC-361), Eisenhower Consortium for Western Environmental Forestry Research.

[1983]

INTRODUCTION

Quaking aspen (*Populus tremuloides* Michx.) stands are among the most important recreational resources of the forested mountains and plateaus of the southwestern United States. The visual contrast of the white trunks and pale green foliage in spring and summer, or the golden fall coloration, with the surrounding conifers and grassland is admired by tourists and residents alike. In addition to their value as a recreational resource, aspen forests are prized for their wildlife, livestock, and fuelwood uses. Recently there has been widespread concern for the lack of aspen regeneration which has resulted in an abundance of decadent, overmature stands with a paucity of vigorous young and intermediate-aged stands (Schier 1975, Patton and Jones 1977, and others).

Aspen reproduces primarily by sprouting (suckering) from shallow lateral roots after fire or windthrow (Gruell and Loope 1974). Most authors (Gruell and Loope 1974, Jones 1974, Patton and Jones 1977, Schier 1975, and others) consider that fire suppression has greatly decreased aspen reproduction. However, since aspen occurs over such a wide elevational and climatic range, we suspect that fire exclusion has had highly variable effects depending on the particular aspen type examined.

Although stringers of aspen occur along water courses at elevations as low as 1500 to 1800 m, aspen stands are generally restricted to elevations of 2000-3250 m (Covington 1975, Little 1950). At higher elevations aspen stands are intermingled with spruce and fir or mixed conifer forests. Here temperatures are relatively cool and precipitation high. Understory vegetation typically consists of a variety of broad leaved herbaceous plants and seedlings or saplings of the surrounding conifers. In this type the natural fire regime was one of infrequent (70-200 yr), high intensity fires which

occurred after sufficient conifer litter and crown fuels had accumulated. Such fires were typically stand replacement fires which killed most, if not all, of the aspen.

At lower elevations aspen stands occur as more or less isolated islands within the predominant ponderosa pine-bunchgrass type. Here precipitation is lower and temperatures higher giving rise to an understory dominated by bunchgrasses. The natural fire regime in this type was most likely one of frequent (2-5 yr), low intensity fires which seldom caused aspen mortality.

Thus fire exclusion would have quite different effects in low elevation aspen communities compared to those at higher elevations. The purpose of this research was to examine the effects of controlled burning in the aspen-bunchgrass type of northern Arizona. Aspen suckering and overstory mortality as well as understory changes were measured; since understory burning in nearby ponderosa pine had greatly increased inorganic nitrogen content of the mineral soil (Ryan and Covington, in review; Covington and Sackett, in review), soil ammonium and nitrate concentrations were also measured.

METHODS

Study Area

The four study sites are located approximately 32 km northwest of Flagstaff, Arizona, on sections 4, 8, 9, and 18 of T 23 N and R 6 E, Gila and Salt River Meridian (Appendix A). Study sites are bounded on the north by Kendrick Park and to the southeast by U.S. Highway 180. All plots are at an elevation of approximately 2450 meters and were selected as typical of the aspen-bunchgrass community. The area is entirely within the Coconino National Forest, Coconino County, Arizona.

The general climate of the study area is described as cool and subhumid (Schubert 1974). The mean annual temperature is 6 C, with monthly averages of -4 C in January and 17 C in July (Pearson and Jameson 1967). Seasonal high temperatures often exceed 4 C in the winter and 27 C during the summer months, while seasonal lows are -18 C and 1 C respectively. The average length of the growing season varies from 117 to 160 days (Clary 1975).

Precipitation typically occurs in two distinct periods. Winter precipitation originates primarily from the Pacific Ocean and results in an average annual snowfall of 231 cm. Summer rains are in the form of thundershowers resulting from moisture laden air originating in the Gulf of Mexico (Kangieser 1966), with an average of 20.6 cm of precipitation between July and September. Precipitation on our study sites during these months was slightly higher than average with 23 cm and 25 cm for 1981 and 1982, respectively.

The soils of the study sites are a Brolliar stony clay loam of cinder and basaltic parent material (Miller and James 1967). Surface soils of this type are moderately fine textured and a dark colored, cobbly or stony loam, with reddish brown clay loam or clay subsoils. Basalt bedrock is at depths of 76 to 152 cm. These soils have a slow permeability (.15 to .50 cm/hr), and a high shrink-swell potential and available water capacity (.13 to .16 in/in); pH is 6.1 to 7.3.

The study sites are best described as an aspen-bunchgrass community, composed of an aspen overstory with an understory of various bunchgrass species. The site index ranges from 30 to 60 and the overstory age is 45 to 55 years. Ages were determined using methods described by Trujillo (1975). Average heights of trees range from 11.0 to 14.6 meters with diameters of 16.2 to 21.6 cm/dbh. Older, larger trees are scattered occasionally throughout the area,

representing relics of an earlier community. Stand data for each plot are presented in Table 1.

Understory vegetation at the sites is dominated by typical bunchgrass species such as Arizona fescue (_Festuca arizonica_ Vasey), mountain muhly (_Muhlenbergia montana_ (Nutt.) Hitck.), and squirreltail (_Sitanion longifolium_ J.G. Smith). A variety of forbs are also present including western yarrow (_Achillea lanulosa_ Nutt.), lupine (_Lupinus_ spp.) fleabane (_Erigeron_ spp.), and American vetch (_Vicia americana_ Muhl.).

The aspen on all plots have been subject to various damaging agents. White trunk rot, caused by _Phellinus tremulae_ (Bond.) et Boris, is prevalent throughout the study area. Other diseases including artist's conk (_Ganoderma applanatum_ (Pers. ex Walls.) Pat.), Ceratocystis canker (_Ceratocystis fimbriata_ Ell. & Halst.), Cytospora canker (_Cytospora chrysosperma_ Pers. ex Fr.), Hypoxylon canker (_Hypoxylon mammatum_ (Wahl.) Mill.), and scaly Pholiota (_Pholiota spuarrosa_ (Fr.) Kumm.) occur occasionally. Browsing on aspen sprouts during the fall months has also been observed.

The land surrounding the study area is managed primarily for forage and timber production. All plots are on the Wild Bill Cattle Allotment which is on a rest rotation grazing system. The season of use is June 1 through September 30, with cattle migrating to the north end of the allotment by the season's end (P. Bocher, pers. comm.). This migration has resulted in substantially greater use and disturbance by cattle on plot four than other plots. The last harvesting of ponderosa pine in the vicinity occurred in 1976. Aspen throughout the area is collected for fuelwood.

Fuel conditions and fire behavior

The quantity of woody fuels, herbaceous fuels, and litter was determined for all plots prior to burning. Woody fuel weights were determined for fuel classes

Table 1. Average height, age, diameter, and site index of aspen trees at all plots.

Study Site	n	Height (m)	Age	Diameter (cm)	Site Index[a]
1	19	13.1 (2.0)	48(6.4)	16.3 (2.8)	55
2	24	14.6 (3.7)	54(1.8)	21.6 (14.7)	60
3	31	10.7 (1.4)	50(5.5)	16.2 (2.8)	45
4	15	11.0 (1.5)	47(7.3)	18.5 (4.1)	50

[a] from curves developed by Jones (1966).

of 0-2.5 cm, 2.5-5 cm, 5-7.6 cm, and greater than 7.6 cm, using methods and prediction equations presented by Brown (1974) and modified by Sackett (1980). Woody fuels were also classified by timelag fuel moisture class (Fosberg and Deeming 1971). Herbaceous fuel loading was estimated using average weight values determined from clipped quadrats adjacent to the burned plots. Litter depth and percent moisture immediatley prior to burning were also determined. Fuel conditions are presented in Table 2.

In October of 1981 treatment plots were burned. Prevailing winds during the burning were 5-10 km per hour from the southwest, with temperatures of 10-15 C. Initially, backing fires were started on the plots, then short strip fires were utilized. Flame length ranged from approximately 15 to 30 cm. The percent of area burned in each plot was estimated (see below) following burning (Table 2).

Sampling Design and Data Analysis

At each study site two 100 m^2 plots were established, one serving as a burn plot, the other a control. Within each plot 30 permanently established, 20 x 50 cm quadrats were systematically located for inventory of understory vegetation and determination of percent burned (Appendix B). All plots were fenced to prevent use by cattle.

Plots were inventoried in July of 1981 prior to burning and again in July of 1982 during the first post-burn growing season. Understory vegetation was sampled at each of the 20 x 50 cm quadrats within each plot. Data concerning species composition, density, and percent cover were recorded for all species present in each sampling quadrat. Species composition was evaluated using Czekanowski's index of similarity (Goodall 1973). All aspen sprouts present within each plot were tallied and mapped, and heights were recorded in 1981 and 1982.

Table 2. Fuel characteristics and percent of area burned for each plot.

	Plot 1	Plot 2	Plot 3	Plot 4
Wood fuels (t/ha)				
0-2.5 cm dia.	.23	.23	.08	.11
2.5-5.0 cm dia.	1.35	2.08	.37	2.94
5.0-7.6 cm dia.	10.19	6.04	0.00	9.86
7.6 cm dia.	16.58	4.30	6.14	27.55
Total	28.35	12.65	6.59	40.46
Herbaceous fuels (kg/ha)	91.40	370.00	783.00	339.00
Moisture content (%)	45	41	36	36
Ave. litter depth (cm)	2.30	3.30	2.10	1.10
Moisture content (%)	31	23	15	13
Percent Burned	61	50	43	10

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Understory production was estimated using regression equations developed for this study (see below). Oven-dry weight of green material was predicted using percent cover and density as independent variables. Cover and density were estimated on 10 quadrats adjacent to each plot. All vegetation within each quadrat was then clipped and separated by species. Green material was sorted from brown and oven-dried at 80 C for 48 hours. Equations were then developed to predict weight from cover and density data for each quadrat to determine the annual production. We assumed that all green material represented the current year's production. This may prove somewhat inaccurate because some green material may be residual from the previous years growth while some of the brown material might have been produced during the current year. Loss by grazing may also result in an underestimate.

The prediction equations for understory production had significant R^2 values ranging from 0.76 to 0.98. These regression equations were developed using the 1978 version of BMDP-1R (Dixon and Brown 1979) and are presented in Appendix A. Equations developed from the 1981 data were used for prediction of production for both 1981 and 1982.

Soils were sampled along systematically located transects adjacent to the understory plots. Five composite samples consisting of four individual soil samples each were collected using a 2.5 cm diameter soil sampling tube. Soils

were separated into 0-5 and 5-15 cm depths before compositing. Composite samples were sieved and thoroughly mixed and then a 10-20 g subsample was extracted immediately with 100 ml of acidified (ph = 2.5) 1NKCl (with phenyl mercuric acetate as a preservative). At the same time another subsample was added to a moisture tin for soil moisture determination. This allowed us to express our results on an oven-dry weight basis. The extractant was analyzed colorimetrically for ammonium and nitrate using the Technicon AutoAnalyzer within a few days of sampling. Ammonium and nitrate are expressed as nitrogen, i.e., ammonium x 14/18 = ammonium-nitrogen and nitrate x 14/62 = nitrate nitrogen.

For vegetation data, analysis of covariance was used to detect significant differences in means between burn and control plots. Data collected in 1981 were used as a covariate to account for annual variation in growing conditions. The data were analyzed as a one-factor (treatment) randomized complete block (plots) design. The model for the analysis of covariance is:

$$y(ij) = \mu + (i) + \tau(j) + \rho(x(j) - x..) + e(ij)$$

where y(ij) = an observed value, = the population mean, (i) = the treatment effect, (j) = the location or block effect, (x(ij) - X..) = the covariance effect, and e(ij) = random error.

The experiment was designed to detect any change in understory vegetation and therefore a two-tailed test was used. However, the aspen sprout experiment tested for an increase in sprouting and soil nitrogen; therefore, the calculated F value was converted to a t value and a one-tailed test was used. Due to the limited sample size and high variation between plots, an alpha level of .10 was used to test for significance in vegetation data. Tests were conducted using the 1978 version of BMDP-2V (Dixon and Brown 1979).

For statistical analysis of soils data a two-tailed t-test was used to test for significant differences between burn and controls for each sampling date. Since data from nearby soil studies suggested that our soil sampling scheme was adequate for picking up meaningful differences, we used an alpha level of .05 to t test for soil differences.

RESULTS AND DISCUSSION

Effects on Aspen Sprouting

Production of aspen sprouts was stimulated by the burning. Although sprout density increased on all plots, burn plots increased to 2.1 times the pre-burn level while controls increased by only 1.7 times (Table 3). Plots one, two, and three showed the most dramatic increase in sprouting. These plots had the greatest area burned, with 45-61 percent of the ground area affected by the fire. At site four, the control plot showed a slightly greater (although not significant) increase in sprouting than the burn. This is attributed primarily to the low degree of burning, in which only 10 percent of the ground area was consumed, and to heavy grazing which occurred prior to the experiment. Grazing and trampling by cattle may serve to reduce competing understory vegetation and disturb the soil, both important factors contributing to increased sprout production (Zasada 1972).

These results are consistent with the findings of other researchers. Horton and Hopkins (1965) found sprout production on burned plots in Ontario, Canada, to increase 4.5 times more than controls. Bartos and Mueggler (1979) found similar results when examining the effects of prescribed burning on aspen in western Wyoming. They found that sprout density on moderately burned plots (21-80 percent of fine fuels consumed by fire) was two times greater than controls in the first year following burning. Sprouts increased to even higher levels in the second year but decreased dramatically in the third.

Increased sucker production following burning may be attributed to various factors. High intensity fires resulting in overstory mortality often reduce the influence on the roots of apical dominance and cause changes in hormonal concentrations. The resulting high ratio of cytokinins to auxins stimulate bud development and shoot growth of suckers (Schier 1976; Eliasson 1971). Although the fires in this study were not of sufficient intensity to cause overstory

Table 3. Average aspen sprout density (per ha) at each plot and all plots combined

	Plot 1		Plot 2		Plot 3		Plot 4		Treatment Mean		
Year	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	p-value[a]
1981	200(231)[b]	200(231)	200(231)	1,600(1,348)	1,900(1,192)	200(231)	1,800(516)	1,200(460)	1,025(953)	800(711)	.09
1982	1,100(756)	400(325)	1,200(1,264)	2,000(1,424)	3,600(2,956)	400(326	2,700(1,740	2,500(1,052)	2,150(1,212)	1,325(1,087)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 4

mortality, similar hormonal changes may have occurred in shallow roots which were severed or damaged by the fire.

High soil temperature is perhaps the most important environmental factor affecting sprouting by aspen (Schier 1976; Zasada and Schier 1973). The blackened soil surface resulting from fire warms earlier in the spring and stimulates chemical activity within the roots, thus making stored food more readily available (Tew 1981). Therefore, it is expected that localized soil temperatures during the fire, and resulting blackened soil, made important contributions to increasing sprout production.

Effects on Understory Vegetation

The response of understory vegetation to burning was highly variable among sites and among species. In some cases, understory vegetation also showed a differing response depending on whether measured as changes in production, percent cover, or density. The effects of burning on changes in production of grasses, forbs, and grasses and forbs combined are presented in Table 4. Production on both burn and control plots increased between 1981 and 1982, with average understory production of grasses and forbs combined increasing 1.2 times on burn plots and 1.6 times on controls. Forb production was also significantly affected, with controls increasing 2 times their 1981 levels and burn plots increasing 1.6 times. Although grass production was greater on control than burn plots, this difference was not statistically significant.

The effects of burning on production of individual species varied considerably between species (Table 5). Overall grass production decreased, primarily because of mountain muhly which decreased significantly, and Arizona fescue which also decreased, although not significantly. Both of these species are dominant grasses of the area and greatly contribute to the total production. This is contrasted to squirreltail and *Carex* spp. in which production significantly increased, while fringed brome (*Bromus ciliatus*, L.) and muttongrass (*Poa*

Table 4. Production (kg/ha) by plant classification at each plot and all plots combined

Plant Classification	Year	Plot 1		Plot 2		Plot 3		Plot 4		Treatment Mean		
		Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	p-value[a]
Grasses	1981	69.8(3.3)[b]	49.4(8.7)	152.2(27.3)	110.4(23.5)	457.7(21.4)	322.0(40.9)	186.3(42.9)	172.2(4.71)	216.5(168.1)	163.5(116.9)	.127
	1982	165.9(11.1)	98.1(21.5)	166.5(12.4)	200.4(21.4)	392.4(41.1)	379.7(80.5)	206.7(5.9)	228.2(40.6)	232.9(108.0)	226.6(116.5)	
Forbs	1981	8.7(5.2)	0.3(0.3)	210.0(38.4)	201.0(67.8)	134.0(13.0)	119.7(19.2)	97.0(26.0)	122.9(30.3)	112.4(83.6)	111.0(82.8)	.094
	1982	16.6(12.5)	2.0(3.0)	280.2(17.3)	356.1(64.4)	199.5(140.8)	247.8(34.5)	213.0(38.1)	267.6(39.7)	177.3(112.8)	218.4(151.7)	
Grasses & Forbs	1981	78.5(2.2)	49.7(8.9)	363.3(43.4)	311.4(76.3)	591.7(15.7)	441.7(22.9)	283.3(18.0)	295.2(29.6)	329.2(212.1)	274.5(163.6)	.047
	1982	182.5(1.7)	100.1(21.5)	446.6(4.9)	556.5(71.6)	591.8(158.2)	127.5(51.5)	419.7(32.5)	495.8(38.9)	410.1(169.5)	320.0(239.6)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 3

Table 5. Production (kg/ha) of grass species at each plot and all plots combined

		Plot 1		Plot 2		Plot 3		Plot 4		Treatment Mean		
Species	Year	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	p-value[a]
Squirrel-tail	1981	10.6(4.3)[b]	13.0(2.6)	6.8(5.5)	16.3(12.4)	55.3(22.9)	17.9(7.0)	11.5(12.5)	17.6(2.9)	21.0(22.9)	16.2(2.2)	.084
	1982	37.2(5.6)	22.9(9.5)	31.7(22.2)	44.5(15.9)	6.3(10.4)	29.5(12.8)	53.9(11.7)	43.1(15.6)	32.3(19.7)	35.0(10.5)	
Mutton-grass	1981	4.3(4.4)	0.0(0.0)	23.0(1.1)	19.9(11.1)	0.0(0.0)	1.1(1.8)	76.1(30.6)	59.2(34.6)	25.8(34.9)	20.5(27.6)	.198
	1982	20.8(17.2)	1.8(1.8)	31.9(7.1)	27.8(14.2)	0.0(0.0)	2.8(4.8)	55.3(18.5)	49.0(14.1)	27.0(23.0)	20.4(22.6)	
Arizona fescue	1981	20.9(5.4)	29.3(12.1)	21.7(18.2)	24.4(12.9)	253.3(63.6)	104.2(34.7)	9.2(12.1)	23.5(22.9)	76.3(118.1)	45.3(39.3)	.144
	1982	31.3(17.5)	46.0(23.7)	27.8(24.6)	41.1(23.3)	171.6(16.2)	120.8(40.7)	11.2(19.4)	39.6(42.0)	60.5(74.6)	61.9(39.4)	
Mountain muhly	1981	32.1(6.1)	7.1(2.3)	81.9(9.2)	40.7(15.3)	133.3(58.1)	196.4(68.8)	59.6(33.1)	67.2(49.2)	76.7(42.9)	77.8(82.7)	.051
	1982	52.4(11.5)	26.4(12.4)	51.9(34.6)	77.9(36.1)	135.3(57.3)	217.0(107.8)	39.7(17.6)	74.3(57.6)	69.8(44.0)	98.9(82.2)	
Fringed brome	1981	1.9(1.2)	0.0(0.0)	12.3(21.3)	1.5(2.6)	10.4(6.8)	1.9(2.3)	16.4(18.2)	0.4(0.6)	10.2(6.1)	1.2(0.6)	.388
	1982	13.0(9.4)	0.0(0.0)	12.3(10.7)	0.0(0.0)	13.8(6.5)	9.7(7.9)	29.0(25.3)	17.5(12.9)	17.0(8.0)	6.8(8.5)	
Carex	1981	0.0(0.0)	0.0(0.0)	6.5(4.1)	7.6(4.1)	6.4(1.8)	0.4(0.4)	13.5(5.6)	4.3(1.7)	6.6(5.5)	3.1(3.6)	.012
	1982	11.2(6.6)	0.9(1.6)	10.9(6.7)	9.2(3.5)	8.3(2.0)	0.0(0.0)	17.7(6.3)	4.6(2.4)	12.0(4.0)	3.7(4.2)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 3

fendleriana, (Steud.)) Vasey) increased slightly, but not significantly.

Production of forbs was significantly lower on burn plots than controls. Lupine and flebane both decreased but not to significant levels, while western yarrow and American vetch showed no detectable difference between burn and control plots (Table 6).

Results concerning the effects of burning on percent cover of grasses, forbs, and grasses and forbs combined are presented in Table 7. The percent cover of all grass species combined showed no significant difference between control and burn plots. The effects of burning on forb cover, although not significant, was variable between sites. Plot one had an initially low forb cover which increased by 5.7 times on the burn plot in 1982, but only slightly on the control. Plots two, three, and four had a higher initial forb cover and showed a slight decrease or no change as a result of burning. Total cover of understory vegetation showed no significant difference between burn and control plots, although cover of plot one increased slightly.

Although no significant differences in percent cover were apparent when examining groups of species, some differences did occur with individual species. Percent cover of squirreltail and carex both increased significantly, while mountain muhly and Arizona fescue both showed a non-significant decrease (Table 8). Although total forbs showed no significant difference between burn and control plots, western yarrow increased slightly while lupine decreased on plot two, three, and four and remained unchanged on plot one (Table 9). Other species remained unchanged or had a varied response between plots.

The effects of burning on density of understory vegetation are presented in Table 10. Grass density increased significantly more on burn (1.3 times) than control (1.2 times) plots at all four sites. Density of forbs showed no significant difference between burn and control plots. Forbs on sites one, two, and four showed slight increases in density, while density on plot three declined.

Table 6. Production (kg/ha) of forb species at each plot and all plots combined

		Plot 1		Plot 2		Plot 3		Plot 4		Treatment Mean		
Species	Year	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	p-value[a]
Western yarrow	1981	7.9(5.6)[b]	0.0(0.0)	7.6(2.9)	1.4(0.7)	9.4(5.8)	23.5(23.5)	33.9(19.9)	34.6(7.2)	14.6(12.9)	14.9(17.0)	.764
	1982	8.7(8.8)	0.0(0.0)	4.6(1.4)	1.2(0.4)	9.5(5.7)	31.3(33.4)	48.2(15.0)	33.9(11.0)	16.5(17.9)	16.6(18.5)	
American vetch	1981	0.8(0.4)	0.0(0.0)	6.9(2.2)	11.5(5.3)	11.9(6.5)	5.2(4.1)	5.9(4.9)	10.9(1.6)	6.4(9.5)	6.9(5.4)	.687
	1982	2.3(0.9)	0.0(0.0)	9.6(2.5)	11.3(2.3)	15.9(9.1)	11.5(3.1)	22.4(6.7)	31.0(6.3)	12.5(8.6)	13.4(12.9)	
Lupine	1981	0.0(0.0)	0.0(0.0)	182.9(34.4)	174.2(67.5)	110.2(11.5)	64.3(15.5)	0.0(0.0)	22.6(17.0)	73.3(89.7)	65.3(77.3)	.134
	1982	0.0(0.0)	0.0(0.0)	254.8(16.5)	320.9(63.8)	163.4(133.2)	149.4(20.0)	28.2(30.4)	116.7(37.8)	111.6(119.2)	146.7(132.6)	
fleabane	1981	0.0(0.0)	0.0(0.0)	4.6(4.8)	9.8(7.7)	0.0(0.0)	26.1(10.9)	39.3(16.2)	35.2(8.4)	11.0(19.0)	17.8(15.8)	.208
	1982	5.4(5.0)	1.8(3.2)	3.3(2.8)	11.6(8.1)	0.0(0.0)	53.3(12.7)	96.0(29.6)	66.6(9.5)	26.2(46.6)	33.3(31.5)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 3

Table 7. Percent cover by plant classification at each plot and all plots combined

		Plot 1		Plot 2		Plot 3		Plot 4		Treatment Mean		
Plant Classification	Year	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	p-value[a]
Grasses	1981	5.5(5.3)[b]	4.1(3.7)	14.5(9.5)	11.3(6.0)	46.2(20.0)	27.0(13.8)	23.0(16.6)	20.3(17.3)	22.3(17.5)	15.7(10.0)	.876
	1982	17.8(11.4)	10.2(9.2)	19.9(12.8)	21.6(9.7)	37.9(1.30)	32.8(11.7)	25.5(11.8)	24.6(15.0)	25.3(9.0)	22.3(9.3)	
Forbs	1981	1.9(2.9)	0.4(0.8)	24.6(14.9)	17.7(15.1)	16.8(13.3)	13.7(8.0)	13.6(8.6)	16.2(7.7)	14.2(9.4)	12.0(7.9)	.329
	1982	10.9(17.7)	0.9(2.2)	32.6(18.4)	35.1(21.7)	32.5(20.8)	40.3(15.3)	37.7(20.3)	38.6(12.9	28.4(11.9)	28.7(18.7)	
Grasses & Forbs	1981	7.3(6.7)	4.5(3.7)	39.1(17.7)	29.0(16.8)	63.0(22.9)	40.7(15.6)	36.6(18.0)	36.5(19.0)	36.5(22.8)	27.7(16.2)	.724
	1982	28.7(21.7)	11.1(9.2)	52.5(18.9)	56.7(21.4)	70.5(18.9)	72.9(16.8)	63.2(24.9)	63.2(16.9)	53.7(18.2)	51.0(27.4)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 30

Table 8. Percent cover of grass species at each plot and all plots combined

		Plot 1		Plot 2		Plot 3		Plot 4		Treatment Mean		
Species	Year	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	p-value[a]
Squirrel-tail	1981	0.9(0.3)[b]	1.1(0.1)	0.9(0.8)	1.9(1.4)	6.6(3.0)	2.1(1.1)	1.5(1.5)	2.1(6.1)	2.5(2.8)	1.8(0.5)	.038
	1982	4.8(0.9)	3.4(0.8)	5.3(1.3)	5.9(2.0)	7.7(1.4)	3.7(1.8)	6.9(1.8)	5.2(2.0)	6.2(1.3)	4.5(1.2)	
Mutton-grass	1981	0.3(0.3)	0.0(0.0)	3.2(0.4)	2.5(1.6)	0.0(0.0)	0.2(0.3)	12.4(6.4)	10.0(7.2)	4.0(5.8)	3.2(4.7)	.372
	1982	2.8(1.8)	0.2(2.5)	4.6(1.2)	4.1(2.5)	0.0(0.0)	0.5(8.7)	7.8(2.4)	7.5(2.5)	3.8(3.3)	3.1(3.4)	
Arizona fescue	1981	1.7(0.2)	2.5(1.2)	2.4(2.1)	2.5(1.4)	28.1(7.1)	11.4(4.1)	1.0(1.3)	2.6(2.6)	8.3(13.2)	4.7(4.4)	.111
	1982	3.3(2.0)	4.6(2.4)	3.1(2.8)	4.4(2.5)	18.5(2.0)	13.2(4.8)	1.2(2.1)	4.3(4.8)	6.5(8.0)	6.6(4.4)	
Mountain muhly	1981	2.1(0.4)	0.5(0.1)	5.4(0.6)	2.7(1.0)	8.7(3.8)	12.9(4.5)	3.9(2.2)	4.4(3.2)	5.0(2.3)	5.1(5.4)	.050
	1982	3.4(0.6)	1.7(0.8)	3.4(2.3)	5.1(2.4)	8.9(3.8)	14.2(7.0)	2.6(1.1)	4.9(3.8)	4.6(2.9)	6.5(5.4)	
Fringed brome	1981	0.2(0.1)	0.0(0.0)	1.1(1.9)	0.1(0.2)	0.9(0.6)	0.2(0.2)	1.5(1.6)	0.1(0.1)	0.9(0.5)	0.1(0.1)	.388
	1982	1.2(0.8)	0.0(0.0)	1.1(0.9)	0.0(0.0)	1.2(0.6)	0.9(0.7)	2.6(2.3)	1.6(1.2)	1.5(0.7)	0.6(0.8)	
Carex	1981	0.0(0.0)	0.0(0.0)	1.6(1.0)	1.6(0.8)	1.3(0.1)	0.1(0.1)	2.9(1.4)	1.0(0.4)	1.4(1.2)	0.7(0.8)	.007
	1982	2.2(1.3)	0.2(0.3)	2.3(1.4)	2.1(0.8)	1.6(0.2)	0.0(0.0)	3.6(1.0)	1.0(0.5)	2.4(0.8)	0.8(0.9)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 3

Table 9. Percent cover of forb species at each plot and all plots combined

		Plot 1		Plot 2		Plot 3		Plot 4		Treatment Mean		
Species	Year	Burn	Control	Burn	Control	Burn	Control	Burn	Control	Burn	Control	p-value[a]
Western yarrow	1981	0.6(0.4)[b]	0.0(0.0)	1.8(0.9)	0.2(0.0)	1.3(0.6)	2.5(2.4)	3.8(2.6)	3.2(0.5)	1.9(1.4)	1.5(1.6)	.113
	1982	5.4(4.5)	0.0(0.0)	2.0(0.9)	0.5(03)	3.5(1.9)	5.3(4.4)	9.1(2.2)	6.8(1.0)	5.0(3.1)	3.1(3.4)	
American vetch	1981	0.1(0.1)	0.0(0.0)	2.5(1.4)	1.6(0.8)	2.4(1.4)	0.6(0.4)	0.7(0.6)	1.1(0.1)	1.4(1.2)	0.8(0.7	.738
	1982	1.5(0.6)	0.0(0.0)	3.3(0.7)	4.3(0.4)	5.7(2.3)	5.0(2.1)	9.0(3.4)	8.7(0.9)	4.9(3.2)	4.5(3.6)	
Dande-lion[c]	1981	0.0(0.0)	0.1(0.1)	1.9(0.4)	1.0(0.5)	0.8(0.8)	0.1(0.2)	3.8(1.4)	3.9(1.9)	1.6(1.6)	1.3(1 .8)	.831
	1982	0.1(0.1)	0.1(0.1)	1.6(0.3)	2.2(1.0)	2.2(0.1)	0.5(0.3)	3.7(0.6)	3.9(1.1)	1.9(1.5)	1.7(1.7)	
Lupine	1981	0.0(0.0)	0.0(0.0)	10.9(1.9)	10.5(4.0)	6.6(6.1)	3.5(1.5)	0.3(0.0)	1.7(0.7)	4.5(5.3)	3.9(4.6)	.130
	1982	0.0(0.0)	0.0(0.0)	14.9(1.0)	18.6(3.8)	9.5(7.7)	8.7(1.2)	1.6(1.7)	6.8(2.2)	6.5(7.0)	8.5(7.7)	
Indian paint-brush[d]	1981	0.0(0.0)	0.0(0.0)	0.6(0.2)	1.3(1.3)	0.1(0.2)	0.1(0.1)	0.3(0.3)	0.0(0.0)	0.2(0.3)	0.3(0.6)	.529
	1982	0.0(0.0)	0.0(0.0)	1.8(0.1)	2.6(1.6)	0.9(1.2)	1.2(2.1)	0.4(0.7)	0.0(0.0)	0.8(0.7)	0.9(1.2)	
fleabane	1981	0.0(0.0)	0.0(0.0)	0.6(0.7)	1.0(0.8)	0.0(0.0)	2.2(1.0)	3.3(0.5)	2.8(0.4)	1.0(1.6)	1.5(1.2)	.125
	1982	0.6(0.6)	0.2(0.3)	0.5(0.5)	1.7(1.3)	0.0(0.0)	5.4(0.9)	8.8(2.6)	7.6(1.6)	2.5(4.2)	3.7(3.4)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 3

[c]*Taraxacum* spp.

[d]*Castilleja integra* Grey.

Table 10. Density (per m^2) by plant classification at each plot and all plots combined

Plant Classification	Year	Plot 1 Burn	Plot 1 Control	Plot 2 Burn	Plot 2 Control	Plot 3 Burn	Plot 3 Control	Plot 4 Burn	Plot 4 Control	Treatment Mean Burn	Treatment Mean Control	p-value[a]
Grasses	1981	5.4(4.6)[b]	3.6(2.1)	6.4(3.8)	6.8(2.6)	10.0(3.8)	5.4(3.0)	9.2(5.2)	6.0(2.4)	7.7(2.2)	5.4(1.4)	.001
	1982	8.8(6.6)	3.8(2.7)	7.9(4.7)	7.4(4.2)	10.8(5.0)	6.1(2.0)	12.8(9.2)	8.9(3.9)	10.1(2.2)	6.5(2.2)	
Forbs	1981	2.6(3.1)	0.4(0.8)	9.7(6.2)	7.2(5.0)	7.1(4.0)	13.4(5.8)	15.0(10.7)	18.8(7.6)	8.6(5.2)	9.9(7.9)	.816
	1982	3.3(3.7)	0.5(1.0)	10.8(7.6)	7.2(5.5)	9.0(6.7)	19.9(11.2)	24.3(13.3)	20.9(7.9)	11.8(8.9)	12.1(9.9)	
Grasses & Forbs	1981	8.1(5.9)	4.0(2.3)	16.1(7.6)	14.0(6.4)	17.1(5.4)	18.8(6.5)	24.1(13.7)	24.8(8.5)	16.3(6.5)	15.4(8.8)	.006
	1982	12.0(8.3)	4.3(3.0)	18.7(8.9)	14.6(7.5)	19.8(7.8)	24.4(6.8)	37.1(18.0)	29.7(9.4)	21.9(10.7)	18.2(11.2)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 30

Total density of grasses and forbs combined showed a significant increase on burned plots.

The effects of burning on density of individual species was variable (Tables 11 and 12). Squirreltail and carex were the only species showing significant differences in density between burn and control plots; both increased. Mutton-grass increased slightly on all sites. Other grasses and forbs showed no significant changes in density.

The results concerning the effects of burning on percent cover and density were difficult to interpret. Although some species exhibited a uniform response to burning at all sites, others were highly variable from one site to another. This variation may be attributed to site differences in microclimate, initial species composition, intensity of burning, and management practices prior to the experiment, as well as random and experimental error.

The net effect of burning on understory vegetation of these aspen stands was varied. In the first year after burning, production of grasses and forbs declined while percent cover remained unchanged and density of grasses increased. Bartos and Mueggler (1979) found similar results from a study of prescribed burning of aspen in western Wyoming. Understory production on their moderately burned plots (21-80 percent of fine fuels consumed by fire) showed a decrease from a preburn level of approximately 1,800 kg/ha to 1,200 kg/ha in the first year following burning. However, production in subsequent years increased dramatically. Production two years after burning was 1.6 times greater than preburn levels and 1.3 times greater in year three.

Studies examining the effects of prescribed burning on understory production in ponderosa pine show no clear trends. Andariese (1982) found no change in understory production two years after burning and increased production in years seven and eleven. Ffolliott et al. (1977) reported no change in first year production on sites with overstory basal area of 70 m/ha and increasing pro-

Table 11. Density (per m^2) of grasses at each plot and all plots combined

Species	Year	Plot 1 Burn	Plot 1 Control	Plot 2 Burn	Plot 2 Control	Plot 3 Burn	Plot 3 Control	Plot 4 Burn	Plot 4 Control	Treatment Mean Burn	Treatment Mean Control	p-value[a]
Squirrel-tail	1981	12.7(5.8)[b]	14.0(4.4)	3.3(2.5)	13.3(10.7)	41.0(16.1)	13.7(2.5)	7.3(8.5)	12.7(6.0)	16.1(17.1)	13.4(0.6)	.007
	1982	22.3(6.8)	14.3(0.6)	26.3(9.4)	24.7(10.1)	45.7(5.7)	20.0(5.3)	34.3(4.0)	31.7(9.9)	32.1(10.3)	22.7(7.4)	
Mutton-grass	1981	6.7(7.2)	0.0(0.0)	19.0(4.6)	18.7(8.3)	0.0(0.0)	0.3(0.5)	42.0(4.3)	28.7(4.0)	16.9(18.5)	11.9(14.2)	.124
	1982	17.7(21.2)	1.7(1.5)	24.3(4.2)	19.7(6.1)	0.0(0.0)	1.0(1.7)	43.7(17.2)	32.0(6.6)	21.4(18.0)	13.6(15.0)	
Arizona fescue	1981	12.3(10.1)	16.7(4.16)	3.7(2.3)	7.0(2.6)	27.3(5.1)	14.3(2.5)	2.0(2.6)	2.3(1.5)	11.3(11.7)	10.1(6.6)	.665
	1982	6.0(1.0)	13.3(8.4)	3.7(2.1)	8.0(4.4)	29.0(1.7)	16.3(2.3)	2.0(3.5)	5.7(2.1)	10.7(11.2)	10.4(5.4)	
Mountain muhly	1981	15.7(3.0)	5.3(0.6)	29.3(8.1)	17.3(7.1)	13.0(3.0)	22.0(1.7)	14.3(4.0)	10.3(3.0)	18.1(7.6)	13.7(7.4)	.819
	1982	16.7(9.1)	6.7(3.0)	7.0(4.0)	11.0(4.6)	13.3(1.1)	20.0(5.6)	8.3(2.3)	7.3(0.6)	11.3(4.5)	11.2(6.1)	
Fringed brome	1981	3.7(1.1)	0.0(0.0)	3.0(5.2)	1.0(1.7)	4.7(1.5)	1.3(1.5)	5.7(5.0)	0.3(.57)	4.3(1.2)	0.6(0.6)	.684
	1982	3.3(2.1)	0.0(0.0)	2.0(2.0)	0.0(0.0)	4.3(2.5)	3.0(1.7)	6.3(6.8)	6.0(3.0)	4.0(1.8)	2.2(2.4)	
Carex	1981	0.0(0.0)	0.0(0.0)	5.7(3.7)	11.0(6.2)	10.0(2.0)	1.3(1.1)	20.3(6.6)	5.7(1.5)	9.0(8.6)	4.5(5.0)	.038
	1982	21.3(13.0)	2.0(3.5)	15.7(12.0)	11.0(4.4)	15.3(7.6)	0.0(0.0)	30.3(17.4)	5.7(3.2)	20.6(7.0)	4.7(4.8)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 3

Table 12. Density (per m^2) of forbs at each plot and all plots combined

Species	Year	Plot 1 Burn	Plot 1 Control	Plot 2 Burn	Plot 2 Control	Plot 3 Burn	Plot 3 Control	Plot 4 Burn	Plot 4 Control	Treatment Mean Burn	Treatment Mean Control	p-value[a]
Western yarrow	1981	11.3(8.1)[b]	0.0(0.0)	10.7(4.2)	2.0(1.0)	13.7(8.3)	34.0(33.9)	49.0(28.8)	50.0(10.5)	21.2(18.6)	21.5(24.6)	.765
	1982	12.7(12.7)	0.0(0.0)	6.7(2.1)	1.7(0.6)	13.7(8.1)	45.3(48.3)	69.7(21.8)	49.0(15.9)	25.7(29.5)	24.0(26.8)	
American vetch	1981	1.3(0.6)	0.0(0.0)	11.0(3.5)	18.3(8.5)	19.0(10.4)	8.3(6.5)	9.3(7.8)	17.3(2.5)	10.1(7.2)	11.0(8.6)	.691
	1982	3.7(1.5)	0.0(0.0)	15.3(4.0)	18.0(3.6)	25.3(14.5)	18.3(5.0)	35.7(10.6)	49.3(10.1)	20.0(13.7)	21.3(20.3)	
Dandelion[c]	1981	0.0(0.0)	0.7(0.6)	6.7(1.5)	8.7(3.8)	4.0(2.0)	0.3(0.6)	35.7(8.9)	42.7(13.3)	11.6(16.3)	13.1(20.1)	.251
	1982	0.3(0.6)	0.3(0.6)	7.7(2.1)	11.3(6.6)	7.7(3.0)	2.3(0.6)	20.7(2.5)	30.3(7.1)	9.1(8.5)	11.0(13.7)	
Lupine	1981	0.0(0.0)	0.0(0.0)	25.0(4.4)	26.0(10.5)	14.3(1.5)	12.0(2.6)	1.0(0.0)	5.7(3.8)	10.1(11.9)	10.9(11.2)	.631
	1982	0.0(0.0)	0.0(0.0)	21.7(4.2)	22.0(9.8)	11.7(9.1)	11.3(3.8)	1.7(0.6)	7.7(4.0)	8.8(10.0)	10.2(9.1)	
Indian Paintbrush[d]	1981	0.0(0.0)	0.0(0.0)	2.0(1.0)	3.0(3.5)	1.0(1.7)	0.7(1.1)	1.7(1.5)	0.0(0.0)	1.2(0.9)	0.9(1.4)	.995
	1982	0.0(0.0)	0.0(0.0)	4.0(2.0)	5.3(2.3)	2.0(2.0)	2.3(4.0)	1.7(2.9)	0.0(0.0)	1.9(1.6)	1.9(2.5)	
fleabane	1981	0.0(0.0)	0.0(0.0)	3.7(3.2)	9.3(7.4)	0.0(0.0)	29.0(11.3)	44.0(24.2)	40.3(11.9)	11.9(21.5)	19.6(18.3)	.420
	1982	4.7(4.5)	1.7(2.9)	1.7(1.5)	7.6(4.0)	0.0(0.0)	25.3(15.3)	101.0(32.1)	58.3(6.6)	26.8(49.5)	30.0(29.4)	

[a]Probability of significant change on burned plots, determined using analysis of covariance.

[b]Mean (Standard Error), n = 3

[c]*Taraxacum* spp.

[d]*Castilleja integra* Grey.

duction on sites with overstory basal area of 39 m/ha. Campbell et al. (1977) reported increased herbage production in the first two years following a spring wildfire in Arizona ponderosa pine.

The response of individual species to burning in our study was generally consistent with results found elsewhere. In the southern Rocky Mountains, mountain muhly and Arizona fescue are often damaged in initial years following burning (Wright and Bailey 1982). Squirreltail is often not as severely damaged by burning, possibly due to its low density of dead material and quick burning (Wright 1971). Bartos and Mueggler (1979) also found decreased production of forbs in the first year following burning. The major species which declined were lupine, locoweed (*Astragalus* spp.) and Fendler meadowrue (*Thalictrum fendleri*, Engelm). Although not important species in our study, these authors report fireweed (*Epilobium augustifolium*, L.) and lambsquarter (*Chenopodium fremontii*, Wats.) increasing on burned plots.

Effects on Species Composition

Changes in species composition were evaluated using Czekanowski's index of similarity. The formula for the index is:

$$\text{Similarity} = \frac{2\sum_{1}^{i} \min}{\sum_{1}^{i} X, Y}$$

The numerator represents the sum of the minimum density values (min) for each species between each plot pair and the denominator is the sum of all densities for each species in plots X and Y. This index provides a value of relative similarity between plots based on species presence and density. A similarity matrix comparing all plots in 1981 is presented in Table 13. Table 14 compares the species compostition of all plots before burning in 1981, with that of 1982 after burning.

The similarity matrices serve two purposes. Table 13 identifies the major similarities or differences present between plots in 1981 before treatments were

Table 13. Similarity matrix[a] comparing species composition of all plots in 1981.

	1B[b]	1C	2B	2C	3B	3C	4B	4C
1B	1.00							
1C	.54[c]	1.00						
2B	.37	.13	1.00					
2C	.42	.29	.69[c]	1.00				
3B	.41	.35	.43	.54	1.00			
3C	.41	.29	.40	.45	.54[c]	1.00		
4B	.29	.11	.41	.45	.33	.50	1.00	
4C	.27	.14	.39	.48	.37	.59	.81[c]	1.00

[a]Values produced using Czekanowski's index of similarity.

[b]Identifies plots 1 through 4, burn (B) and control (C).

[c]Similarity ratio of paired burn and control plots at the same site.

Table 14. Similarity matrix[a] comparing species composition for all plots between 1981 and 1982.

		1981							
		1B[b]	1C	2B	2C	3B	3C	4B	4C
	1B	.61[c]	.31	.48	.57	.48	.39	.47	.38
	1C	.55	.83[c]	.20	.36	.35	.33	.15	.19
	2B	.30	.21	.65[c]	.61	.52	.40	.43	.49
1981	2C	.37	.30	.61	.88[c]	.59	.39	.43	.48
	3B	.39	.31	.40	.52	.89[c]	.52	.35	.36
	3C	.35	.26	.36	.44	.56	.76[c]	.55	.58
	4B	.20	.11	.29	.38	.39	.38	.70[c]	.62
	4C	.26	.15	.36	.45	.43	.46	.73	.74[c]

[a] Values produced using Czekanowski's index of similarity.

[b] Identifies plots 1 through 4, burn (B) and control (C).

[c] Similarity ratio of each plot in 1981, compared with the same plot in 1982.

applied. Examination of the data shows, as expected, that the greatest degree of similarity was between burn and control plots at the same site. The degree of similarity between plots at different sites was highly variable. Although some plots showed a high degree of similarity in species composition and density with plots at other locations, other plots showed very little similarity with other study sites.

Table 14 compares the change in species similarity of burn plots before and after burning in 1981 and 1982, with that of controls. Plots one and two show the most dramatic change in species similarity between years as a result of burning. Both sites showed an average of .22 percent less similarity on burn plots than controls. The difference in species similarity on burned plots is attributed primarily to changes in grass composition. Both plots had a relatively low density of grasses prior to burning, which increased significantly on burned plots. The primary increasers were squirreltail, carex, and fringed brome, while density of Arizona fescue declined. Density of forbs was changed very little at both sites.

Results of species similarity from sites three and four are not consistent with sites one and two. The burned plots of site three show 13 percent greater similarity between 1981 and 1982 than did the controls. On this site the increase of both grasses and forbs was greater on control than burn plots. The increased density of the control plot was possibly stimulated by favorable growing conditions, which served to offset the decrease in density of the dominant grasses, mountain muhly and Arizona fescue. The change in percent similarity between years at site four was consistent between burn and control plots.

Effects on Soil Ammonium and Nitrate

Soil ammonium-nitrogen and nitrate-nitrogen were only slightly increased by the burning. Nitrate-nitrogen in the 0-5 cm depth significantly greater on burned plots than controls immediately after burning (Table 15). Although the burned plots remained higher in July following burning, these differences had disappered by the fall. No significant differences in nitrate-nitrogen occurred in the 5-15 cm depth.

Although ammonium-nitrogen was not significantly higher on burned plots immediately after burning (Table 16), burned plots were significantly higher than controls at the 0-5 cm depth in the summer and fall after burning. In the 5-15 cm depth the burned plots were significantly higher immediately before burning as well as in the fall 1 year after burning. Why they were higher before burning is uncertain, although contamination from elk or cattle use is a possible cause, especially before the plots were fenced.

That soil nitrogen was only slightly affected by this low intensity burn is not surprising. Burning in nearby ponderosa pine has demonstrated that increases in soil ammonium and nitrate the first year after burning are substantial only where fairly heavy fuels are consumed (Ryan and Covington, in review).

Table 15. Nitrate-nitrogen concentration of the mineral soils.

Sampling date	Burn	Control
	mg/g	
0 - 5 cm depth		
7/81	.078 (.0848)[a]	.773 (.7041)
preburn '81	.254 (.0993)	.109 (.1505)
postburn '81	.066 (.0091)*	.035 (.0075)
7/82	.483 (.1545)*	.155 (.0228)
10/82	.306 (.0667)	.292 (.1083)
5 - 15 cm depth		
7/81	.039 (.0043)	.155 (.1123)
preburn '81	.204 (.1112)	.075 (.0253)
postburn '81	.037 (.0063)	.025 (.0062)
7/82	.139 (.0244)	.106 (.0458)
10/82	.214 (.0751)	.129 (.0330)

[a]Mean and (standard error), n = 20. Five samples for Significant (p = .05) differences between burn each of four plots and control are marked by an asterisk.

Table 16. Ammonium-nitrogen concentrations of the mineral soil.

Sampling date	Burn	Control
	mg/g	
0 - 5 cm depth		
7/81	16.12 (2.40)[a]	12.48 (4.27)
preburn '81	5.92 (.629)	4.49 (.556)
postburn '81	4.21 (.505)	3.10 (.349)
7/82	12.97 (1.630)*	8.11 (.955)
10/82	6.57 (.560)*	4.75 (.294)
5 - 15 cm depth		
7/81	6.53 (.672)	4.67 (.762)
preburn '81	2.48 (.176)*	1.81 (.156)
postburn '81	1.89 (.204)	1.68 (.157)
7/82	5.51 (.621)	4.26 (1.094)
10/82	3.17 (.210)*	2.37 (.192)

[a]Mean and (standard error), n = 20. Five samples for each of Significant (p = .05) differences between burn and control are four plots marked by an asterisk.

Chapter 5

SUMMARY AND MANAGEMENT IMPLICATIONS

Prescribed burning of four aspen-bunchgrass sites in northern Arizona stimulated aspen sucker production and had a varied effect on understory vegetation and soil nitrogen. Increased sucker density was highest on plots which had the greatest percent of the area burned. Production of understory vegetation decreased as a result of burning, while density increased and percent cover showed no significant change. The response of individual species varied. Some dominant species, such as Arizona fescue and mountain muhly, decreased in production and percent cover, while squirreltail and carex increased.
Soil ammonium and nitrate were significantly increased in the 0-5 cm depth, although changes were small.

Prescribed fire may prove an effective tool in stimulating moderate sucker production and regeneration in aspen-bunchgrass stands in Arizona. Although burning stimulates suckering, it may be necessary to burn extensive areas to ensure sprout survival of competition and grazing pressures. The benefits of fire as a tool in the management of understory vegetation in aspen-bunchgrass communities is uncertain. Our study shows a decrease in understory production one year following burning; however, based on the results of other studies understory production is expected to increase in subsequent years.

Although these results are from only four plots, they should give a good indication of the effects of low intensity prescribed burning in aspen-bunchgrass communities in northern Arizona. Additional research of the long term responses of aspen sprouts and understory vegetation to burning and the effects of different fire intensities would further improve our understanding of the role of fire in the aspen-bunchgrass type.

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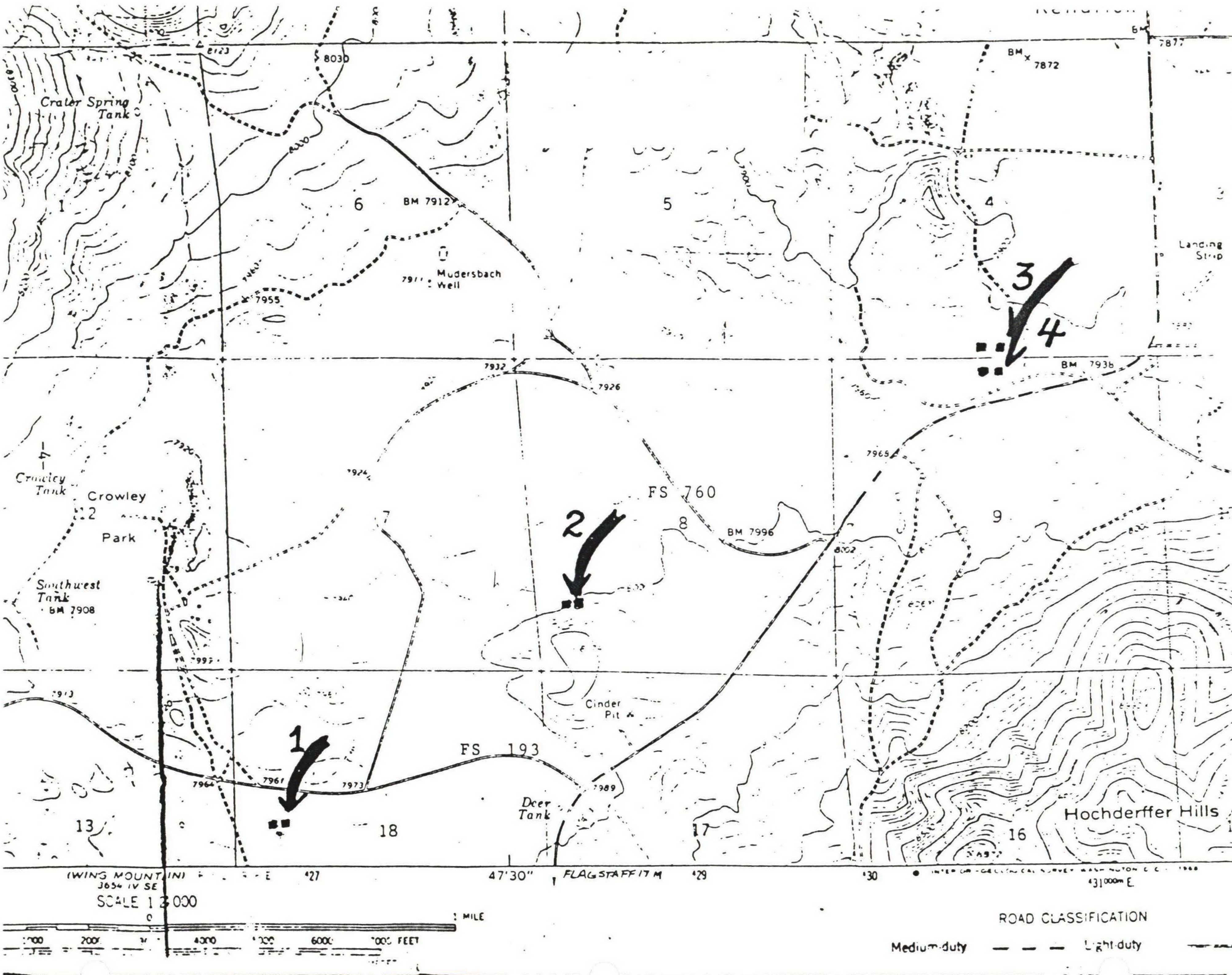
APPENDIX A

LOCATION OF STUDY PLOTS

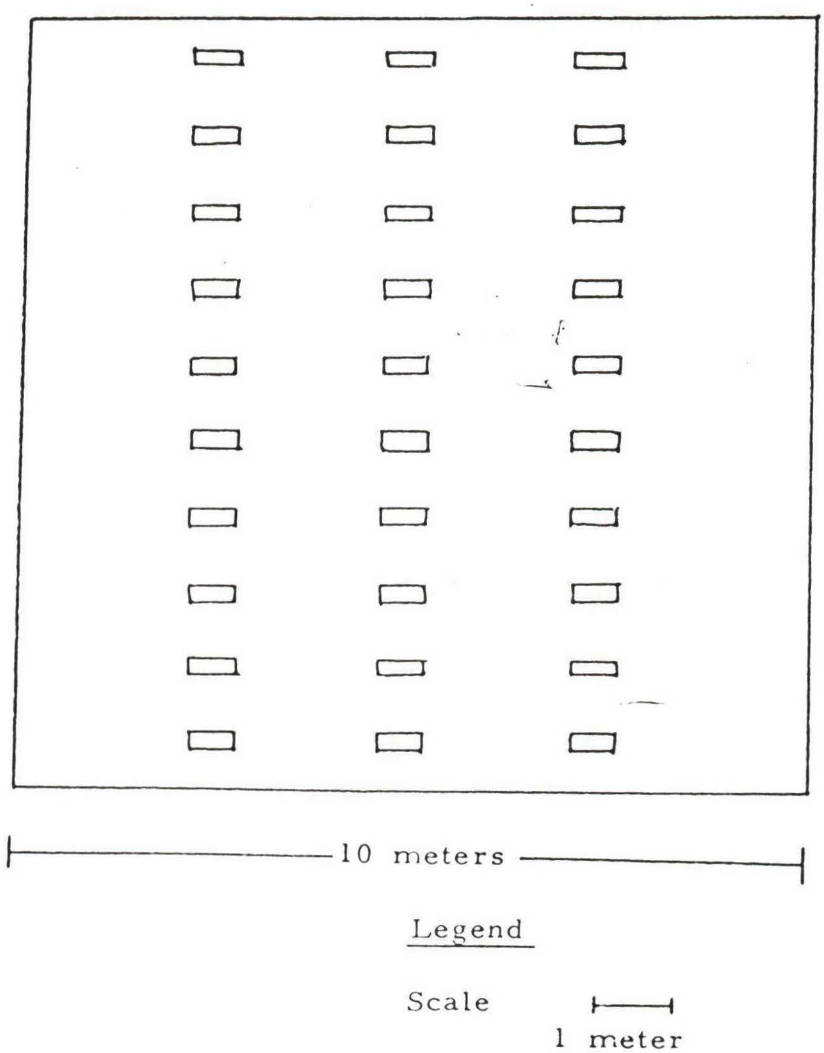


Crater Spring Tank
8030
BM 7912
Mudersbach Well
7955
BM x 7872
Landing Strip
1
6
5
4
3
3
4
2
1
BM 7936
7932
7926
7965
Crowley Tank
Crowley Park
12
Southwest Tank
BM 7908
7
FS 760
8
BM 7996
8002
9
Cinder Pit
FS 193
7961
7964
7973
7989
Deer Tank
13
18
17
16
Hochderffer Hills
15
(WING MOUNTAIN)
3654 IV SE
427
47'30"
FLAGSTAFF 17 M
429
430
431000m E.
SCALE 1:24 000
1 MILE
4000
6000
7000 FEET
ROAD CLASSIFICATION
Medium-duty
Light-duty

APPENDIX B

SAMPLE PLOT LAYOUT

SAMPLE PLOT LAYOUT



APPENDIX C

REGRESSION EQUATIONS USED TO PREDICT PLANT WEIGHT

Appendix C. Regression equations predicting plant dry weight of grasses in and carex g (Y) using percent cover (X_1) and Density per m^2 (X_2) as predictor variables.

Species	Equation[a]	n	SEE[b]	R^2
Squirreltail	$Y = 0^c + .058\ (X_1) + .050\ (X_2)$	12	.278	.81
Arizona fescue	$Y = 0 + .085\ (X_1) + .050\ (X_2)$	15	.881	.88
Muttongrass	$Y = 0 + .046\ (X_1) + .044\ (X_2)$	9	.102	.98
Mountain muhly	$Y = 0 + .153\ (X_1)$	15	1.217	.88
Fringed brome	$Y = 0 + .127\ (X_1) + -\ .035\ (X_2)$	6	.189	.93
Carex	$Y = 0 + .036\ (X_1) + .016\ (X_2)$	7	.159	.90

[a] all equations are significant at the p = .05 level

[b] Standard error of the estimate.

[c] Y-intercept set at zero.

Appendix C (continued). Regression equations predicting plant dry weight of forbs in g (Y) using percent cover (X_1) and density per m^2 (X_2) as predictor variables.

Species	Equation[a]	n	SEE[b]	R^2
Western yarrow	$Y = 0^c + .069\ (X_2)$	5	.174	.76
American vetch	$Y = 0 + .063\ (X_2)$	7	.099	.83
Lupine	$Y = 0 + .177\ (X_2) + -.044\ (X_2)$	12	.327	.98
Erigeron	$Y = 0 + .044\ (X_2) + .057\ (X_2)$	7	.315	.97

[a]All equations are significant at the p = .05 level.

[b]Standard error of the estimate.

[c]Y-intercept set at zero.